# Life Cycle Analysis of Electric Vehicle Batteries

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***Abstract-*** *Electric vehicles' (EVs') ecological affect is a significant worry as automotive industry gets ready to switch to electricity. In order to precisely and scientifically evaluate ecological efficiency of Electric Vehicles, they looked at ecological effects of Electric Vehicles during their entire life cycle oras contrasted with gasoline-powered cars. Since batteries make up the majority of an EV's structural components, we include list ecological implications of the making of batteries, consumption, secondary usage, remaking or reusing. The findings proved that EVs have a greater negative environmental impact than ICEVs throughout the production phase due to battery manufacture. [11,12] Even though the amount of renewable energy generatedmostly determined this, EVs in the usage phase received higher iceVs. The environmental benefits of EVs are increased by reusing and remanufacturing retired batteries throughout the recycling process.However, EVs have greater negative consequences with regard to of usage, than cars with combustion engines of metals & minerals as well as the potential for human toxicity. Electric Vehiclehas the ability tominimizeProduction of greenhouse gasesor the use of specimen fuels over their entire life cycle. The promotion of EVs widely, the manufacturing of closed-loop battery, & the feasible growth of economy, atmosphere, or resources all depend on strengthening electoral foundation, modernizingbattery innovation, as well as increasing recycle performance.[2,4]*

## I. INTRODUCTION

With the arrival of electric automobiles, particularly electrical automobiles for passengers, there have never been the greater possibility for cut include urban air quality and transportation-related emissions of greenhouse gases industry. with relation to the adequacy of urban air.

According to a recent research estimated fifty thousand unexpected deaths annually just because of pollution in the European Union, where accessibility is available, the main source of atmosphere pollution, particularly in the urban areas. This idea is supported by the fact that electric vehicles (EVs) have no tailpipe emissions, which is also supported by the fact that EVs have no emissions.[16]

These are some things to think aboutdon't, however, allow us to conclude that EVs are preferable to gasoline engine vehicles, as it's difficult to comparison between Electric Vehicles and gasoline engine Vehicles using just pollutants produced during a vehicle's using phase. To exactly comparison betweengasoline engine Vehicles with Electric Vehicles, Scientists should think about to effects in relation to the production of Electricity, oil and gas, cars, or batteries, as well as aspects of death in life cycle assessments of Electric Vehicles.[7,9] To study the environmental impacts that arise over the course of a vehicle's whole life cycle, an LCA technique should be utilized.Over past ten years, there have surely been many LCAs comparing EVs and ICE vehicles, as well as many literature reviews on the topic. In actuality, the powertrain and batteries are the two most significant distinctions between EVs and ICEs, making them essential parts of EVs. Additionally, the production of batteries uses energy and has an impact on the environment, which could negate some of the benefits of utilizing electric vehicles, especially with regard to emissions that contribute to climate change.[13,16] The purpose of this study is to analyze this issue and to offer methodological advice to researchers who want to carry out future LCA studies on the batteries of EVs. It does this by providing an overview of the existing LCA studies.

### Why Perform Life Cycle Analysis?

The Life cycle analysis may be used for assess the benefits and drawbacks of an innovation. This has been completedin the study to looking at Its ecological consequences, notably energy use and emissions of carbon dioxide ($CO_2$), during the vehicle's life. When purchasing a new automobile, It is connected with significant imports and exports. System imports include things like energy use, natural resource intake, and water use, while system outflows include things like trash and emissions.[18,28] compared to average mileage, emissions from the tailpipe assist us in evaluating the efficiency of various automobiles, they only provide us a partial picture because they only contrast flows connected to vehicle operation; none of the flows linked to phases before vehicle operation have been taken into consideration. This information will be helpful to City of Vancouver decision-makers, and the division responsible for equipment services may use it to strategically plan for the eventual electrification of its fleet of vehicles.[6]

**Basic Information**

Using the terms automobile battery life-cycle evaluation and automobile batteries life cycle, and ecological consequences of electric car batteries, a search of Google Scholar was conducted to finish the review of the literature.

Based on search outcomes, we only select pieces that demonstrated the traits listed below:

- Discarding any articles that explore Other uses for batteries and concentrating only on Battery life cycle assessment (LCA) in automobiles applications (such as for stationary use).
- Records that analysis every stage of the battery's life cycle, including as manufacture and disposal recycling phases, or list the components and procedures that have an impact on the environment.
- Studies contrasting different battery types with variations in their the field of chemistry strength, density of energy, and ability to store are all important considerations.
- Reviews of automobiles battery articles.
- Analysis of theparticular design of batteries that identifies primary effects brought on by the usage of materials and activities and suggests environmentally friendly alternatives.[14,22]

## II. LITERATURE REVIEW

**Objectives and Purpose**

The objective of the LCA must be specified along with the intended application, the driving factors or reasons for doing the research, and target the audience. If the outcomes are supposed to beutilized into comparison claims for use of public should also be specified in the purpose definition. The processes that will make up the product system under investigation, as well as the service that the product system and the associated functional unit provide, must be described. Additionally, allocation procedures—that is, how to divide input or output—are The defining of objective and scope, also known as the scoping process. Normally, it is necessary to revisit the subjects that were discussed at the scoping step.[21,28]

**Inventory Evaluation**

The life cycle inventory analysis collects, verifies, and standardizes data on physical flows across system boundaries With respect to the regard movement for the useful unit of production. Procedure diagrams for sequences that include individual processthat make up under-investigation products systems are widely usesfororganize the gathering data procedure as well as gain a general grasp of the life cycle.[7]

There may be hundreds of different emissions and resources included in an Eco profile, which is a summary of the inputs, outputs, and resources used in the product system.

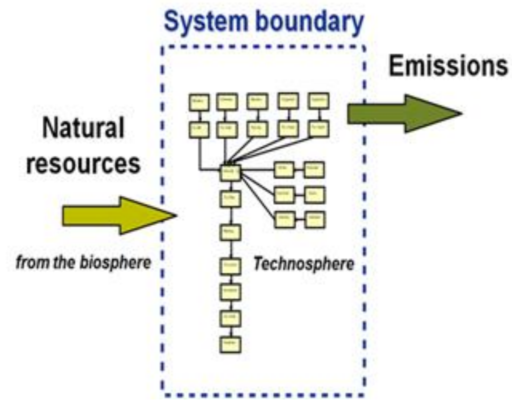


**Figure-1: Demonstrates how analysis of the life cycle inventory takes into consideration actual flow rates throughout the substance's component boundary region.[7]**

**ImpactEvaluation**

The evaluation of the life cycle effect makes perception simpler to incorporating the Inventory of the life cycle. The completely automated LCA software technique known as LCIA matches the supply as well as exit chemicals in terms of the environment effect characterization variables of the effect categories selected. Remember that there will be no potential impact if a medicine is left off of the life cycle inventory (LCI), if the EIA technique's characterization element is not used, and if the substance's name is incorrect.[4,5]

**Interpretation**

The process of life cycle interpretation entails returning to Given fresh information, the concerns from the first objective and definition of scope phase and determining whether In light of the computed findings, the system limits functioning item, as well as information needs are adequate.The initial inferences made. In order to come at a definitive interpretation, the commissioner's team must assist. The phase's outputs are the conclusions, limitations, and suggestions that are specific to Life Cycle Analysis. [8,9]

## III. RESEARCH APPROACHES AND METHODOLOGIES

The history of my research papers, my two research views, and their corresponding units of analysis are presented in the first section of this chapter. Following a reflection on my role as an LCA practitioner in connection to my colleagues in our various projects, the LCA process is examined in light of various philosophical stances, research methodologies, and research procedures. I next briefly go over the frequent literature searches I conducted over the course of my 16-year research project.[18,5]

## IV. RESEARCH PROCESS

Figure shows some of the empirical research from 2004 to 2020. LCA was emphasized as a tool to aid in the development of various battery chemistries starting in 2008. My licentiate thesis included an article on stepwise environmental product declarations (EPDs), an LCA-based eco-label. Its main objective is to enable small firms who want to green any of their goods using LCA (not necessarily batteries).[1,9]

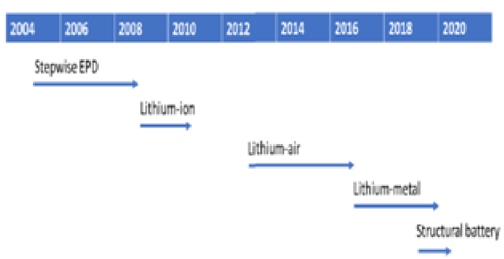


**Figure-2: The study was conducted between 2004 and 2020.[9]**

The concentration using electric power During the past 12 years, Life Cycle Analysis studies of cases have enabled a gradationally better implementation of the LCA methodology. During this time, the wide range of LCAs of traction batteries and electric vehicles served as another source of information and inspiration.

### Two Angles of Research

Examining the outcomes of the LCA case studies from various vantage points or viewpoints is necessary to fully address all of the study issues.

The first research perspective, which is limited to the traction battery under study and is comprised of the mobility batteries research scenarios' numeric Life Cycle Analysis findings, needs to be considered so as to answer the research queries one and two. The dimension of measurement for the Each battery analysis has a functioning component, like a kilograms the LIB power source, delivered Kilowatt-hour and vehicles kilometers.

Answers to study questions 2 and 3 will help us better understand how to use Life Cycle Analysis to lessen negative environment effects & batteries for traction encourage the durable adoption for innovative technologies. The analysis is based on a single Life Cycle Analysis research project.[17]

As previously suggested, Providing a solution to study second question may necessitate considering both viewpoints. Regarding the papers' applicability, only the stepwise EPD article (A) makes use of the LCA perspective, whereas those Every rechargeable batteries-related research research has the same viewpoint.; see Figure below.

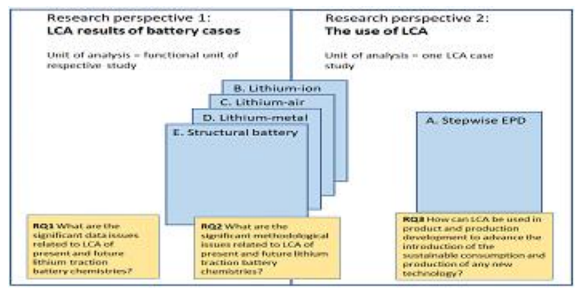


**Figure-3: shows the relationship between the units of analysis, research orientations, and papers.[17]**

### Positionality

In regard to my participants and my setting, who am I as a researcher? The query is in the rows giving the definitions and interpretations of the objective and scope, respectively, partially answers this question. I collaborated with insiders in all of the battery case studies because I considered myself to be an authority in LCA, and my colleagues to be scientists and experts in batteries (Herr and Anderson 2015). Also take note that in the stepwise EPD paper (A), I played a different role in the remaining seven case studies than I did in the three where I collaborated with insiders as an outsider.[19]

We must be conscious of this and prevent the prejudice that will inevitably result by including critical reflexivity into the study process. There are numerous opportunities to communicate with others during the LCA process that can counteract such inescapable bias. The stepwise EPD study used third-party verification as a more formal method of identifying errors and correcting bias in LCA.[24]

**Life Cycle Analysis: A Positivist and Interpretive Approach**

In terms of research methodology, the four stages of LCA contain a wide range of components; differing philosophical stances call for distinct research techniques and methodologies in the various stages. Which illustrates the dynamic nature of LCA practice (see Figure below).

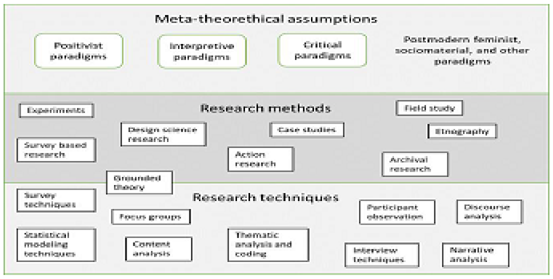


**Figure-4: The methodological landscape.[13]**

Also, Figure below shows the two research vantage points that were utilized in the thesis. In course, the objective and scope, inventory, or impact assessment stages may give rise to the data issues that research perspective 1 examines, but their significance will only become apparent during the interpretation stage.

Application that is meant, the motivations or impetuses for doing the study, and the intended audience must all be described, as stated in the purpose and scope of the LCA.[19,13]

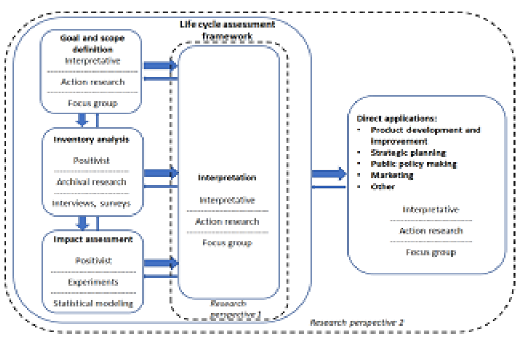


**Figure-5: The four stages of LCA call for various philosophical stances as well as various research strategies. The two various research vantage points applied in the thesis are also displayed.[19]**

During a life cycle analysis of inventories (LCI), information pertaining to the physically system-to-system flowing over borders are obtained, confirmed, normalized to the functional unit's flow of reference. Data gathering throughout inventories necessitates an additional realistic strategy for sciences; an information source, as It has just one optimal numerical information suitable, that could indicate a distribution of probability containing a mean value, as defined by its data. The unit processes that make up the studied product system are determined during an interpretive goal and scope definition stage.[4]

## V. RESULTS AND DISCUSSION

### 5.1 Don't Lose System Perspective and Efficiency

Under the assumption of a typical global electricity mix, a battery system's internal efficiency is a critical consideration from an environmental aspect. Battery LCA assessments that leave out the application step miss associated economic impact. The application phase of a traction battery might have highly varying environmental impacts regarding the electrical mixture.

In contrast, for an electric vehicle (EV) with the normal global electricity mix, the use phase's climate effects contribute to around 80% of overall effects; for a specific illustration, consider the lithium-metal battery.The distribution for toxicity and ozone production is essentially the same since burning fossil fuels to generate electricity is closely related to all three consequence categories. Recycle offers the ability to get back between 10% and 20% of the loads. from the manufacturing stage, or 2-4% of all burdens for climate change, toxicity, and ozone formation. The graphic below presents An illustrationregarding ecology expenses related to a standard Electric Vehicles to aid in comprehension.[4,6]

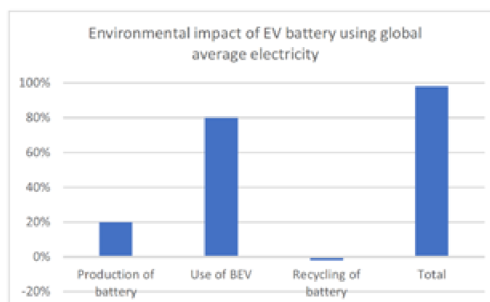


**Figure-6: Graph comparing the environmental effects of battery production, recycling, and battery electric vehicle (BEV) use when using typical European electricity.[6]**

### 5.2 To Reflect the Scarcity of Resources, Use Two Abiotic Depletion Metrics.

It is recommended that two separate biological reduction metrics might be employed in order to follow existing recommendations and take into account the current criticality difficulties. According to the lithium-metal battery article (D), the lithium iron-phosphate (LFP) battery outperformed a lithium-nickel-manganese-cobalt (NMC) battery of comparable size in terms of abiotic depletion. The heavier LFP battery was the cause of this, and it increased the amount of electricity needed during the use phase.[6,8] This contradicts the claims made by Greim, Solomon, and Breyer (2020) and Olivetti et al. (2017) that the manufacturing of the most popular NMC technology can be limited by the lack of cobalt and nickel. The findings of abiotic depletion in the lithium-air battery study also presented difficulties in comprehension due to a recent change in the methodology used. The present abiotic depletion impact assessment methodologies produce noticeably different results in the case of EV batteries, which makes it challenging to interpret the data, according to Peters and Weil.[2]

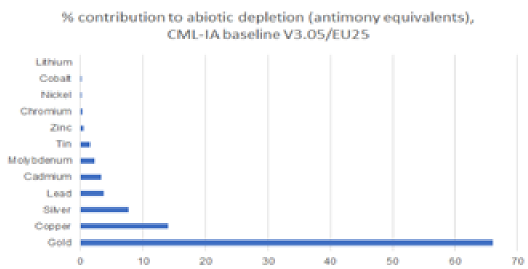


**Figure-7:The life cycle contribution to abiotic depletion is represented by the NMC333 traction battery's antimony equivalents, which were computed using the CML-IA baseline V3.05/EU25.[8]**

**5.3 Result of Every Relevant Structural Sections**

The range for structural sections that are offered under various criteria of the Life Cycle Analysis of Battery powered traction makes it challenging to compare studies, but it is vital because the functional unit choice depends on the study's objectives. Results for each functional unit or reference flow relevant to the investigation should unquestionably be presented.

As stated in introduction, there are various LCA rules that apply to traction batteries, and because the guidelines have various goals, their recommendations about functional units vary.[1] If a standard is used to compare or label batteries instead of different cars, that is where the line is drawn. While the latter utilizes delivered kWh, the former uses vehicle km. Additionally, there are LCA studies that use kWh battery capacity or even kg battery with the goal of debating and providing LCA data. These four functional units were classified by Philippot et al. It is determined by the following metrics: battery weight, energy provided, amount of energy, and distance.

**5.4 Categories of Traction Batteries Environmental Effects**

While using LCA to make improvements, that is recommended for reduce environmental issues effect sections. Changes in the climate, abiotic elements exhaustion, respiration inorganics, acidification as well, and ozone depletion generation are among the most common significant effect sections for traction battery LCA. In battery-related articles throughout all investigations, several sets of environmental effect categories have been used or reported.[9] It is debatable whether to add an impact category given the lack of essential impact characterization factors or emission statistics.

This can create a false sense of security, as was previously discussed. Fair comparisons with ICVs should also be made easier. Many selection criteria are listed in the standard (ISO 2006c), including relevancy, worldwide acceptance, comprehensiveness, etc. The table below offers a rating list of impact categories for traction batteries.

**Table-1: Rankings for traction battery impact categories.[9]**

| Rank | Impact category | Motivation |
|---|---|---|
| 1 | Climate impact | Relevant for both internal combustion vehicles (ICVs) and electric vehicles (EVs). International consensus on science and urgency. Strongly linked to fossil fuel combustion for electricity or in ICVs. |
| 2 | Resource depletion, mineral and metals | Very relevant for EVs. Choose the *ultimate reserve* as the base to follow the current guidelines and/or the *economic reserve base* to reflect current scarcity of battery metals; see Chapter 5.2.1. |
| 3 | Respiratory inorganics/particulate matter | Relevant for both EVs and ICVs. Dust from tyres, brakes and combustion. |
| 4 | Acidification | Strongly linked to fossil fuel combustion for electricity but not so much for vehicle fuel combustion due to regulations. |
| 5 | Ozone formation | Strongly linked to fossil fuel combustion for electricity and in ICVs. |
| 6 | Eutrophication | Strongly linked to fossil fuel combustion for electricity and in ICVs. |

**Limitations**

- Each article in this thesis has specific project-related scope and budgetary constraints. The analysis of the research topics is subject to the same limitations. The study limitations include a shortage of Life Cycle Analysis information regarding certain electric batteries chemistries, as well as several technical problems concerns about traction battery Life Cycle Analysis, as was previously mentioned.
- These gaps are somewhat filled by the appended publications for the chemical types of Freshwater is a solution for lithium ferrous phosphate (LiFePO4), potassium fresh air, potassium over a metallic electrode, or structured LiFePO4 biochemistry. The lithium nickel cobalt aluminum (NCA) potassium oxide and nickel manganese chromium (NMC), though only to a limited extent because they have served as lithium benchmarks.[18,26]
- Limited amounts of potassium oxide and nickel manganese chromium (NMC) and lithium nickel cobalt

aluminum (NCA) Chemistry is additionally included since it has served as a standard for li with metallic anode electrodes. The list doesn't include any other chemistries for traction battery cells. There is just one cell type (pouch, prismatic, or cylindrical) for which a bill of materials is offered. Western European and Swedish power blends, which were employed in the computations, are analogous to the present and upcoming world averages. The recycling phase is completely ignored from the early tests and only tentatively estimated in the subsequent investigations due to a complete lack of data.

## VI. FUTURE SCOPE

- The domains oftravel, environmental issues, & batteries made from lithium-ion all require urgently more research. Here, I'll merely briefly discuss a few subjects that are relevant to my individual research and potential future areas of interest. The application of LCA to lessen environmental effects when developing new battery systems, charging infrastructure, and particularly their chemistry-specific recycling pathways are a few of these. Chemical risk assessment should be used to examine chemical risks from a life cycle viewpoint, particularly those related to recycling.
- A major impediment to fleet electrification is a shortage of charging infrastructure. If you don't have access to a charging station at home (for example, if you live in an apartment), there isn't one available at work, or it's too far to travel to a charging station from your vacation home, then purchasing a vehicle that runs on electricity an acceptable battery capacity or pricing might not be a viable choice. Although the effectiveness of alternative charging systems is mostly unclear, charging infrastructure must be built as a result.[24] Considering that the average for both Europe and the rest of the globe is 500 g of $CO_2$/kWh, Lam et al. (2019) calculate That means that 15 percent of the power disappears earlier it reaches the battery, that equates to an additional 15 g of $CO_2$/km. If the supply is a Solar and wind energy supply Withthe surplus, charger efficiency, becomes less important. Europe has conducted research on dynamic or wireless charging thus far. It is time to start investigating the impact of charging infrastructure on the environment as it is being built and expanded.
- A battery can be stationary (standalone), mobile (in a vehicle), or both to provide system functions like peak shaving and load levelling for a renewable electrical energy system. In order for electrification to have a smaller environmental affects.[28]
- Modern lithium-ion battery (LIB) chemistries contain a lot of poisonous, irritating, volatile, and combustible chemicals. Also, the high voltage used by traction LIB packs throughout their whole lifespan causes safety issues. These safety concerns must be resolved and handled as they are identified during the production and use phases in order for the technology to be introduced. Yet, because the recycling phase is 10–20 years away, safety concerns there are rarely properly investigated.
- The European Commission's new Sustainable Batteries Regulation will put in place an extensive structure that addresses every types of batteries and their complete the life period, including manufacturing methods, layout specifications, or secondary use. It will also cover recycling and the use of recycled materials in new batteries.

## VII. CONCLUSION

The Research Paper comes to the conclusion that there is a huge need for additional study in the broad subject of traction batteries. Only as examples of the author's own research interests, the mitigation of the environmental effects of battery charging and charging infrastructure, as well as during the recycling of various LIB chemistries, are provided.[15,20]

The main the goal of the above thesis or supporting the goal of research is to make the application of Life Cycle Analysis to increase power battery’s ecological efficiency for electric vehicles. This was done primarily by providing inventory data for potential battery chemistries, but it was also done by emphasizing key electro mobility-related variables and methodological concerns. By enabling the expanded and enhanced use of LCA by industries, this thesis also intends to contribute to sustainable industrial and societal transformation in general. Three research questions (RQS) were developed to achieve these goals. The results were most strongly impacted by the significantly lower from the operation stage. Longer lifespan resulted in a stronger movement in favor of electric vehicles in the efficiency balance, according to sensitivity analysis findings.[22,25]

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